CLAIMS

I CLAIM:

1. A spectroscopic ellipsometer for evaluating a sample comprising:

a broadband light source generating a beam having wavelengths extending over a range of at least 200 to 800 nm;

a polarizer disposed in the path of the light beam;

a compensator disposed in the path of the light beam, said compensator for inducing phase retardations in the polarization state of the light beam, said compensator having characteristics other than substantially-non-achromatic so that the amount of phase retardation varies with wavelength, over a range of wavelengths, less than is the case were a substantially-non-achromatic compensator utilized, said compensator being rotated at an angular frequency of ω ;

an analyzer that interacts with the light beam after the beam interacts with the sample and with the compensator;

a detector that measures the intensity of the light beam after the interaction with the analyzer at a plurality of wavelengths across the wavelength range of at least 200 to 800 nm;

said detector generating a time varying intensity output signal simultaneously comprising 2ω and 4ω component signals; and

optionally a processor for evaluating the sample based on

simultaneous use of the intensity output signal 2 ω and 4 ω components.

2. A spectroscopic ellipsometer for evaluating a sample comprising:

a broadband light source generating a beam having wavelengths extending over a range of at least 200 to 800 nm;

a polarizer disposed in the path of the light beam;

a compensator disposed in the path of the light beam, said compensator for inducing phase retardations in the polarization state of the light beam, said compensator having characteristics selected from the group consisting of:

being substantially-achromatic; and
being pseudo-achromatic;

so that the amount of phase retardation varies with wavelength, over a range of wavelengths, less than is the case were a substantially-non-achromatic compensator utilized, said compensator being rotated at an angular frequency of ω ;

an analyzer that interacts with the light beam after the beam interacts with the sample and with the compensator;

a detector that measures the intensity of the light beam after the interaction with the analyzer at a plurality of wavelengths across the wavelength range of at least 200 to 800 nm;

said detector generating a time varying intensity output signal simultaneously comprising 2 ω and 4 ω component signals; and

optionally a processor for evaluating the sample based on simultaneous use of the intensity output signal 2ω and 4ω components.

3. A spectroscopic ellipsometer as in Claim 1, in which applies at least one selection from the group consisting of:

the compensator fast axis azimuthal angle varies with wavelength;

the compensator range of retardations over the range of wavelengths does not include 180 degrees; and

the compensator provides retardance which varies by less than ninety (90) degrees (max - min) over a range of wavelengths, said retardance being within a range of retardations bounded by (30.0) to less than (135) degrees.

4. A spectroscopic ellipsometer as in Claim 2, in which applies at least one selection from the group consisting of:

the compensator fast axis azimuthal angle varies with wavelength;

the compensator range of retardations over the range of wavelengths does not include 180 degrees; and

the compensator provides retardance which varies by less than ninety (90) degrees (max - min) over a range of wavelengths, said retardance being within a range of retardations bounded by (30.0) to less than (135) degrees.

5. A spectroscopic ellipsometer for evaluating a sample comprising:

broadband electromagnetic radiation source means generating a beam having wavelengths extending over a range of at least 200 to 800 nm;

polarizer means disposed in the path of said beam;

compensator means disposed in the path of the beam, said compensator for inducing phase retardations in the polarization state of the light beam, said compensator means being:

pseudo-achromatic;

in that the amount of phase retardation varies more with wavelength, over a range of wavelengths, than is the case if a substantially-achromatic compensator is utilized; but in that the amount of phase retardation varies less with wavelength, over said range of wavelengths, than is the case if a substantially-non-achromatic compensator is utilized, said compensator means being rotated at an angular frequency of ω;

analyzer means that interact with the beam after the beam interacts with the sample and the compensator means;

detector means that measure the intensity of the beam after the interaction with the analyzer means at a plurality of wavelengths across the wavelength range of at least 200 to 800 nm;

said detector means generating a time varying intensity signal simultaneously comprising 2ω and 4ω component signals, said 2ω and 4ω signals being simultaneously present at all wavelengths measured unless the 2ω signal is forced to 0.0 by a sample presenting with an ellipsometric DELTA of 0.0 as opposed to being caused to be 0.0 by said compensator means; and

optionally a processor for evaluating the sample based on simultaneous use of the intensity output signal 2ω and 4ω components.

6. A spectroscopic ellipsometer as in Claim 5, in which applies at least one selection from the group consisting of:

the compensator fast axis azimuthal angle varies with wavelength;

the compensator means range of retardations over the range of wavelengths does not include 180 degrees; and

the compensator provides retardance which varies by less than ninety (90) degrees (max - min) over a range of wavelengths, said retardance being within a range of retardations bounded by (30.0) to less than (135) degrees.

7. A spectroscopic ellispometer as in Claim 5 in which a selection is made from the group consisting of:

the compensator provides retardance which varies by less than ninety (90) degrees (max - min) over a range of wavelengths, said retardance being within a range of retardations bounded by (30.0) to less than (135) degrees over a range of wavelengths defined by a selection from the group consisting of:

a. minimum wavelength is less than/equal to one-hundred-ninety (190) and maximum wavelength greater than/equal to seventeen-hundred (1700) nanometers;

b. minimum wavelength is less than/equal to two-hundred-twenty (220) and maximum wavelength MAXW greater than/equal to one-thousand (1000) nanometers;

c. within a range of wavelengths defined by a maximum wavelength (MAXW) and a minimum wavelength (MINW) range where (MAXW)/(MINW) is at least four-and-one-half (4.5);

and

the compensator means provides retardance of between

seventy-five (75) and one-hundred-thirty (130) degrees over a range of wavelengths defined by a selection from the group consisting of:

d. between one-hundred-ninety (190) and seven-hundred-fifty (750) nanometers;

e. between two-hundred-forty-five (245) and nine-hundred (900) nanometers;

f. between three-hundred-eighty (380) and seventeen-hundred (1700) nanometers;

g. within a range of wavelengths defined by a maximum wavelength (MAXW) and a minimum wavelength (MINW) wherein the ratio of (MAXW)/(MINW) is at least one-and-eight-tenths (1.8).

8. A spectroscopic ellipsometer as in Claim 5 in which the compensator means is caused to rotate by a pulse driven stepper-motor, the position of said rotating compensator being commonly synchronized to corresponding output from said detector.

9. A spectroscopic ellispometer as in Claim 5 in which the compensator means is a selection from the group consisting of:

comprised of a combination of at least two zero-order waveplates (MOA) and (MOB), said zero-order waveplates (MOA) and (MOB) having their respective fast axes rotated to a position offset from zero or ninety degrees with respect to one another;

comprised of a combination of at least a first (ZO1) and a

second (ZO2) effective zero-order wave plate, said first (ZO1) effective zero-order wave plate being comprised of two multiple order waveplates (MOA1) and (MOB1) which are combined with the fast axes thereof oriented at a nominal ninety degrees to one another, and said second (ZO2) effective zero-order wave plate being comprised of two multiple order waveplates (MOA2) and (MOB2) which are combined with the fast axes thereof oriented at a nominal ninety degrees to one another; the fast axes (FAA2) and (FAB2) of the multiple order waveplates (MOA2) and (MOB2) in said second effective zero-order wave plate (ZO2) being rotated to a position at a nominal forty-five degrees to the fast axes (FAA1) and (FAB1), respectively, of the multiple order waveplates (MOA1) and (MOB1) in said first effective zero-order waveplate (ZO1);

comprised of a combination of at least a first (ZO1) and a second (ZO2) effective zero-order wave plate, said first (ZO1) effective zero-order wave plate being comprised of two multiple order waveplates (MOA1) and (MOB1) which are combined with the fast axes thereof oriented at a nominal ninety degrees to one another, and said second (ZO2) effective zero-order wave plate being comprised of two multiple order waveplates (MOA2) and (MOB2) which are combined with the fast axes thereof oriented at a nominal ninety degrees to one another; the fast axes (FAA2) and (FAB2) of the multiple order waveplates (MOA2) and (MOB2) in said second effective zero-order wave plate (ZO2) being rotated to a position away from zero or ninety degrees with respect to the fast axes (FAA1) and (FAB1), respectively, of the multiple order waveplates (MOA1) and (MOB1) in said first effective zero-order waveplate (ZO1); and

comprised of a combination of at least one zero-order

waveplate, (MOA or MOB), and at least one effective zero-order waveplate, (ZO2 or ZO1 respectively), said effective zero-order wave plate being comprised of two multiple order waveplates which are combined with the fast axes thereof oriented at a nominal ninety degrees to one another, the fast axes of the multiple order waveplates in said effective zero-order wave plate being rotated to a position away from zero or ninety degrees with respect to the fast axis of the zero-order waveplate;

10. A spectroscopic ellipsometer as in Claim 5 in which compensator means is comprised of a type selected from the group consisting of:

Berek-type with optical axis essentially perependicular to a surface thereof;

non-Berek-type with an optical axis essentially parallel to a surface thereof;

zero-order wave plate;

zero-order waveplate constructed from two multiple order waveplates;

a sequential plurality of zero-order waveplates, each constructed each from a plurality of multiple order waveplates;

rhomb;

polymer;

achromatic crystal; and

pseudo-achromatic.

11. A spectroscopic ellispometer system as in Claim 5, in which said detector which measures the intensity of the beam after the interaction with the analyzer at a plurality of wavelengths across the wavelength range of at least 200 to 800 nm, receives input via a dispersive optics.

12. A spectroscopic ellipsometer system as in claim 11 in which said dispersive optice is selected from teh group consisting of:

a prism; and

a diffraction grating which is selected from the group consisting of:

a "lined";
a "blazed"; and
a "holographic" geometry;

said lined geometry consisting essentially of symetrical alternating lines with depressions therebetween, and said blazed geometry consisting of alternating ramp shaped lines with depressions therebetween, and said holographic geometry consisting of continuous cosine shaped lines and depressions.

13. A spectroscopic ellipsometer system as in Claim 5, wherein sample reflectance is determined from the detector output signal without application of normalizion to any D.C. and/or A.C. components thereof.

14. A spectroscopic ellipsometer system as in Claim 5 which further comprises a focusing element, for directing the beam onto a sample, disposed in the path of said beam.

15. A spectroscopic ellipsometer system as in Claim 5 in which

the compensator means comprises a plurality of compensators present before and/or after a sample, and a selection is made from the group consisting of:

all said compensators are caused to rotate in use; and

at least one of said compensators is not caused to rotate in use.

16. A spectroscopic ellipsometer system as in Claim 5 in which a fiber optic is present at at least one location selected from the group consisting of:

between said broadband electromagnetic radiation source and the polarizer means;

and

between said analyzer means, and a dispersive optics.

17. A spectroscopic in Claim 16 in which an electromagnetic beam directing means is present after the analyzer, said electromagnetic beam directing means being selected from the group consisting of:

fiber optics, said fiber optics becoming at least bifrucated (LF1) (LF2) (LF3) thereby providing a plurality of fiber optic bundles, at least two of which plurality of at least two bifrucated fiber optic bundles provide input to separate detector systems (DET1) (DET2) (DET3), each of said separate detector systems comprising a dispersion optics and a multiplicity of detector elements;

and

beam splitter means which passes approximately half a beam incident from said analyzer into one detector, and reflects the remainder of said incident beam into a second detector.

18. A spectroscopic ellipsometer system as in Claim 5 which is characterized by a mathematical model comprising calibration parameters, at least one of which is a member of the group consisting of:

effective polarizer means azimuthal angle orientation;

present sample PSI (ψ), as a function of angle of incidence and a thickness;

present sample DELTA (Δ), as a function of angle of incidence and a thickness;

compensator means azimuthal angle orientation;

matrix components of said compensator means;

analyzer means azimuthal angle orientation; and

detector element image persistance (x_n) and read-out (p_n) nonidealities;

which mathematical model is effectively a transfer function which enables calculation of electromagnetic beam magnitude as a function of wavelength detected by a detector element, given magnitude as a function of wavelength provided by said broadband

electromagnetic radiation source; said calibration parameter(s) selected from the group consisting of:

effective polarizer means azimuthal angle orientation;

present sample PSI (ψ), as a function of angle of incidence and a thickness;

present sample DELTA (Δ), as a function of angle of incidence and a thickness;

compensator means azimuthal angle orientation;

matrix components of said compensator means;

analyzer means azimuthal angle orientation; and

detector element image persistance (x_n) and read-out (p_n) nonidealities;

being, in use, evaluated by performance of a mathematical regression of said mathematical model onto at least one, multi-dimensional data set(s), said at least one multi-dimensional data set(s) being magnitude values vs. wavelength and a at least one parameter selected from the group consisting of:

angle-of-incidence of said polychromatic beam of electromagnetic radiation with respect to a present sample; and

effective or actual azimuthal angle rotation

of one element selected from the group consisting of:

said polarizer means; and

said analyzer means;

obtained over time, while compensator means is caused to continuously rotate;

said at least one, multi-dimensional, data set(s) each being normalized to a selection from the group consisting of:

a data set D.C. component;

a data set A.C. component;

a parameter derived from a combinations of a data set D.C. component and a data set A.C. component;

said mathematical model optionally further comprising a reflectance parameter calculated from un-normalized A.C. and/or D.C. components.

19. A method of calibrating a spectroscopic ellipsometer system comprising, in any functional order the steps of:

a. providing a spectroscopic ellipsometer for evaluating a sample comprising:

broadband electromagnetic radiation source means generating a beam having a wavelength extending between over a range of at least 200 to 800 nm;

polarizer means disposed in the path of said beam;

compensator means disposed in the path of the beam, said compensator for inducing phase retardations in the polarization state of the light beam, said compensator means having characteristics other than substantially-non-achromatic, said compensator means being rotated at an angular frequency of ω;

analyzer means that interacts with the beam after the beam interacts with the sample and the compensator means;

detector means that measure the intensity of the beam after the interaction with the analyzer means at a plurality of wavelengths across the wavelength range of at least 200 to 800 nm;

said detector means generating a time varying intensity output signal simultaneously comprising 2ω and 4ω component signals, said 2ω and 4ω component signals being simultaneously present at all wavelengths measured unless the 2 component signal is force to 0.0 by a sample presenting with an ellipsometric DELTA of 0.0 as opposed to being caused to be 0.0 by said compensator means;

b. developing a mathematical model of said spectroscopic ellipsometer which comprises as calibration parameter(s) at least one selection from the group consisting of:

effective polarizer means azimuthal angle orientation;

present sample PSI (ψ), as a function of angle of incidence and a thickness;

present sample DELTA (Δ), as a
function of angle of incidence and a
thickness;

retardations of said compensator means
as a function of wavelength;

compensator means azimuthal angle orientation(s);

matrix components of said
compensator means; and

analyzer means azimuthal angle orientation;

which mathematical model is effectively a transfer function which enables calculation of electromagnetic beam magnitude as a function of wavelength detected by a detector means element, given magnitude as a function of wavelength provided by said broadband electromagnetic radiation source means;

c. causing a polychromatic beam of electromagnetic radiation, produced by said broadband electromagnetic radiation source means, to pass through said polarizer means, interact with a sample caused to be in the path thereof, pass through said analyzer means, and enter detector element in said detector means, said polychromatic beam of electromagnetic radiation also being caused to pass through said compensator means;

d. obtaining at least one, multi-dimensional, data set(s) of magnitude values vs. wavelength and a parameter selected from the group consisting of:

angle-of-incidence of said polychromatic
beam of electromagnetic radiation with
respect to a present sample; and

effective or actual azimuthal angle rotation of one element selected from the group consisting of:

said polarizer means; and

said analyzer means;

over time, while said compensator means is caused to continuously rotate;

said at least one multi-dimensional, data set(s) being obtained utilizing a selection from the group consiting of:

all of said at least one multi-dimensional data set(s), being obtained utilizing a single sample;

at least one of said at least one multi-dimensional data set(s), being obtained utilizing one sample, with another of said at least one multi-dimensional data set(s), being obtained utilizing another sample; and

at least one of said at least one multi-dimensional data set(s) being obtained with the spectroscopic ellipsometer system oriented in a "straight-through" configuration wherein a polychromatic beam of electromagnetic radiation is caused to pass through said polarizer means, pass through said analyzer means, and enter detector elements in said at least one detector system, with said polychromatic beam of electromagnetic radiation also being caused to pass through said compensator means but without being caused to interact with any sample other than open ambient atmosphere;

e1. optionally calculating reflectance from obtained A.C.

and/or D.C. data without peforming any normalization thereupon;

e2. normalizing data in each said at least two, at least one-dimensional, data set(s) with respect to a selection from the group consisting of:

a data set D.C. component;

a data set A.C. component;

a parameter derived from a combinations of a data set D.C. component and a data set A.C. component;

f. performing a mathematical regression of said mathematical model onto said normalized at least one, multi-dimensional, data set(s) and optionally said reflectance, thereby evaluating calibration parameters in said mathematical model;

said regression based calibration procedure serving to evaluate parameters in said said mathematical model for non-achromatic characteristics and/or non-idealities and/or positions of at least one selection from the group consisting of:

effective azimuthal angle of said polarizer means;

azimuthal angle(s) of said compensator means,

retardation of said compensator means as a function of wavelength;

matrix components of said compensator means; and

depolarization/Mueller Matrix
components; and

azimuthal angle of said analyzer means.

g. optionally repeating steps e. and f. utilizing a different selection in step e. in normalizing data.

20. A method of calibrating a spectroscopic rotating compensator material system investigation system as in Claim 19 which further comprises including calibration parameters for detector element image persistance (n_k) and read-out (p_k) nonidealities in the mathematical model, and further evaluating said calibration parameters for detector element image persistance and read-out nonidealities in said regression procedure.

21. A method of calibrating a spectroscopic rotating compensator material system investigation system as in Claim 19 in which the step of developing a calibration parameter containing mathematical model of said spectroscopic rotating compensator material system investigation system includes the steps of providing a matrix representation of each of said polarizer means, present sample, said compensator means, and said analyzer means, and determining a mathematical transfer function relating electromagnetic beam magnitude out to magnitude in, as a function of wavelength, by multiplication of said matrices in a spectroscopic rotating compensator material system investigation system element presence representing order.

22. A method of calibrating a spectroscopic rotating compensator material system investigation system as in Claim 19, which further comprises the step of parameterizing calibration parameter(s) by representing variation as a function of a member of the group consisting of:

wavelength;

angle-of-incidence of said polychromatic beam of electromagnetic radiation with respect to a present sample;

thickness of said sample and/or surface layer thereupon;

effective or actual azimuthal angle orientation of one element selected from the group consisting of:

said polarizer means; and

said analyzer means;

DELTA offset resulting from interaction of said electromagnetic beam with a birefringent element of said spectroscopic rotating compensator material system investigation system; and

wavelength shift in data curve resulting from interaction of said electromagnetic beam with an element of said spectroscopic rotating compensator material system investigation system;

by a parameter containing mathematical equation, parameter(s) in said parameter containing mathematical equation being evaluated during said mathematical regression.

23. A method of calibrating a spectroscopic rotating compensator

material system investigation system as in Claim 22, in which calibration parameter(s) which are parameterized are selected from the group consisting of:

effective polarizer means azimuthal angle orientation;

compensator means azimuthal angle orientation;

matrix components of said compensator means; and

analyzer means azimuthal angle orientation;

each as a function of wavelength.

24. A method of calibrating a spectroscopic rotating compensator material system investigation system as in Claim 22 in which the sample is selected from the group consisiting of:

open atmosphere with the spectroscopic ellipsometer being oriented in a "straight-through" configuration; and

other than open atmosphere with the spectroscopic ellipsometer being oriented in a "sample-present" configuration.

25. A method of calibrating a spectroscopic rotating compensator material system investigation system comprising, in any functional order, the steps of:

a. providing a spectroscopic ellipsometer for evaluating a sample comprising:

broadband electromagnetic radiation source means generating a

beam having a wavelength extending between over a range of at least 200 to 800 nm;

polarizer means disposed in the path of said beam;

compensator means disposed in the path of the beam, said compensator for inducing phase retardations in the polarization state of the light beam, said compensator means having characteristics other than substantially-non-achromatic, said compensator means being rotated at an angular frequency of ω ;

analyzer means that interacts with the beam after the beam interacts with the sample and the compensator means;

detector means that measure the intensity of the beam after the interaction with the analyzer means at a plurality of wavelengths across the wavelength range of at least 200 to 800 nm;

said detector means generating a time varying intensity output signal simultaneously comprising 2ω and 4ω component signals, said 2ω and 4ω component signals being simultaneously present at all wavelengths measured unless the 2ω component signal is force to 0.0 by a sample presenting with an ellipsometric DELTA of 0.0 as opposed to being caused to be 0.0 by said compensator means;

b. developing a mathematical model of said spectroscopic ellipsometer which comprises as calibration parameter variables effective polarizer means azimuthal angle orientation, present sample PSI (ψ), present sample DELTA (Δ), compensator means azimuthal angle orientation, matrix components of said at least one compensator means and analyzer means azimuthal angle orientation, which mathematical model is effectively a transfer

function which enables calculation of electromagnetic beam magnitude as a function of wavelength detected by a detector element, given magnitude as a function of wavelength provided by said broadband electromagnetic radiation source means, said mathematical model providing equations for coefficients of terms in said transfer function, said coefficients of terms each being a function of identified calibration parameters;

c. causing a polychromatic beam of electromagnetic radiation produced broadband electromagnetic radiation source to pass through said polarizer means, interact with a sample caused to be in the path thereof, pass through said analyzer means, and enter detector elements in said at least one detector system, with said polychromatic beam of electromagnetic radiation also being caused to pass through said compensator means;

d. obtaining at least two, at least one-dimensional, data set(s) of magnitude values vs. at least one parameter selected from the group consisting of:

wavelength;

angle-of-incidence of said polychromatic beam of electromagnetic radiation with respect to a present sample; and

effective or actual azimuthal angle rotation of one element selected from the group consisting of:

said polarizer means; and

said analyzer means;

over time, while at least one of said compensator means is caused

to continuously rotate;

said at least at least two, at least one-dimensional, data set(s) being obtained utilizing a selection from the group consiting of:

all of said at least two at least one-dimensional data set(s), being obtained utilizing a single sample;

at least one of said at least two one-dimensional data set(s), being obtained utilizing one sample, with another of said at least two at least one-dimensional data set(s), being obtained utilizing another sample; and

at least one of said at least two at least one-dimensional data set(s) being obtained with the spectroscopic rotating compensator material system investigation system oriented in a "straight-through" configuration wherein a polychromatic beam of electromagnetic radiation is caused to pass through said polarizer means, pass through said analyzer means, and enter detector elements in said at least one detector system, with said polychromatic beam of electromagnetic radiation also being caused to pass through compensator means but without being caused to interact with any sample other than open ambient atmosphere;

e1. optionally calculating reflectance from obtained A.C. and/or D.C. data without peforming any normalization thereupon;

e2. normalizing data in each said at least two, at least one-dimensional, data set(s) with respect to a selection from the group consisting of:

a data set D.C. component;

a data set A.C. component;

a parameter derived from a combinations of a data set D.C. component and a data set A.C. component;

f. performing a mathematical regression of said mathematical model equations for coefficients of terms in said transfer function, onto said at least two at least one-dimensional data sets thereby evaluating calibration parameters in said mathematical model;

said regression based calibration procedure serving to evaluate parameters in said said mathematical model for non-achromatic characteristics and/or non-idealities and/or positions of at least one selection from the group consisting of:

effective azimuthal angle of said polarizer means;

azimuthal angle of said compensator means,

retardation of said compensator means as a function of wavelength;

matrix components of said compensator means; and

depolarization/Mueller Matrix components; and

azimuthal angle of said analyzer means;

g. optionally repeating steps e2. and f. utilizing a different

selection in step e2. in normalizing data.

26. A method of calibrating a spectroscopic rotating compensator material system investigation system as in Claim 25 in which a Hadamard analysis approach is utilized in evaluating numerical values for coefficients of terms in the transfer function for said spectroscopic rotating compensator material system investigation system.

27. A method of calibrating a spectroscopic rotating compensator material system investigation system as in Claim 26 which further comprises including calibration parameters for detector element image persistance (n_k) and read-out (p_k) nonidealities in the mathematical model, and further evaluating said calibration parameters for detector element image persistance and read-out nonidealities in said regression procedure.

28. A method of calibrating a spectroscopic rotating compensator material system investigation system as in Claim 25, in which the step of developing a calibration parameter containing mathematical model of said spectroscopic ellipsometer includes the steps of providing a matrix representation of each of said polarizer means, sample, compensator means and said analyzer means, and determining a transfer function relating electromagnetic beam magnitude out to magnitude in, as a function of wavelength, by multiplication of said matrices in a spectroscopic ellipsometer system element presence representing order.

29. A method of calibrating a spectroscopic rotating compensator material system investigation system as in Claim 25 in which the step of evaluating values of coefficients of terms in a transfer function from said at least one, multi-dimensional, data set(s) involves calculating values of coefficients of a Fourier Series.

30. A method of calibrating a spectroscopic ellipsometer system as in Claim 25 which further comprises the step of parameterizing calibration parameters by representing variation as a function of a member of the group consisting of:

wavelength; and

angle-of-incidence

of said polychromatic beam of electromagnetic radiation with respect to the sample, and effective or actual azimuthal angle orientation of one element selected from the group consisting of:

said polarizer means; and

said analyzer means;

by a parameter containing mathematical equation, said parameters being evaluated during said mathematical regression.

31. A method of calibrating a spectroscopic rotating compensator material system investigation system as in Claim 30, in which calibration parameters which are parameterized are selected from the group consisiting of:

effective polarizer means azimuthal angle orientation;

compensator means azimuthal angle orientation;

matrix components of said compensator means; and

analyzer means azimuthal angle orientation;

each as a function of wavelength.

32. A method of calibrating a spectroscopic rotating compensator material system investigation system as in Claim 25 in which the sample is selected from the group consisiting of:

open atmosphere with the spectroscopic ellipsometer being oriented in a "straight-through" configuration; and

other than open atmosphere with the spectroscopic ellipsometer being oriented in a "sample-present" configuration.

33. A method of calibrating a spectroscopic ellipsometer system, comprising the steps of:

a. providing a spectroscopic ellipsometer for evaluating a sample comprising:

broadband electromagnetic radiation source means generating a beam having wavelengths extending over a range of at least 200 to 800 nm;

polarizer means disposed in the path of said beam;

compensator means disposed in the path of the beam, said compensator for inducing phase retardations in the polarization state of the light beam, said compensator means having characteristics other than substantially-non-achromatic, said compensator means being rotated at an angular frequency of ω;

analyzer means that interact with the beam after the beam

interacts with the sample and the compensator means;

detector means that measure the intensity of the beam after the interaction with the analyzer means at a plurality of wavelengths across the wavelength range of at least 200 to 800 nm;

said detector means generating a time varying intensity output signal simultaneously comprising 2ω and 4ω component signals, said 2ω and 4ω component signals being simultaneously present at all wavelengths measured unless the 2ω component signal is force to 0.0 by a sample presenting with an ellipsometric DELTA of 0.0 as opposed to being caused to be 0.0 by said compensator means;

b. developing a mathematical model of said spectroscopic ellipsometer system which comprises as calibration parameter(s) at least one selection from the group consisting of:

effective polarizer means azimuthal angle orientation;

present sample PSI (ψ), as a function of angle of incidence and a thickness;

present sample DELTA (Δ), as a function of angle of incidence and a thickness;

retardations of said compensator means as a function of wavelength;

compensator means azimuthal angle orientation;

matrix components of said

compensator means; and

analyzer means azimuthal angle orientation;

which mathematical model is effectively a transfer function which enables calculation of electromagnetic beam magnitude detected by a detector element, given magnitude provided by said broadband electromagnetic radiation source means generating a beam having wavelengths extending over a range of at least 200 to 800 nm;

c. causing a polychromatic beam of electromagnetic radiation produced by said broadband electromagnetic radiation source means, to pass through said polarizer means, interact with a sample caused to be in the path thereof, pass through said analyzer means, and enter detector elements in said detector means, with said polychromatic beam of electromagnetic radiation also being caused to pass through said compensator means;

d. obtaining at least one, multi-dimensional data set(s) of magnitude values vs. parameters selected from the group consisting of:

wavelength;

angle-of-incidence of said polychromatic beam of electromagnetic radiation with respect to a present sample;

effective or actual azimuthal angle orientation of one element selected from the group consisting of:

said polarizer means; and

said analyzer means;

over time, while at least one of said at least one compensator means is caused to continuously rotate;

said at least at least one, multi-dimensional data set(s) being obtained utilizing a selection from the group consiting of:

all of said at least one multi-dimensional data set(s), being obtained utilizing a single sample;

at least one of said at least one multi-dimensional data sets being obtained utilizing one sample, with another of said at least one multi-dimensional data sets being obtained utilizing another sample; and

at least one of said at least one multi-dimensional data set(s) being obtained with the spectroscopic ellipsometer oriented in a "straight-through" configuration wherein a polychromatic beam of electromagnetic radiation produced by said broadband electromagnetic radiation source means, generating a beam having wavelengths extending over a range of at least 200 to 800 nm, is caused to pass through said polarizer means, pass through said analyzer means and enter detector elements in said at least one detector system, with said polychromatic beam of electromagnetic radiation also being caused to pass through said compensator means but without being caused to interact with any sample other than open ambient atmosphere;.

e1. optionally calculating reflectance from obtained A.C. and/or D.C. data without peforming any normalization thereupon;

e2. normalizing data in each said at least two, at least one-dimensional, data set(s) with respect to a selection from the

group consisting of:

a data set D.C. component;

a data set A.C. component;

a parameter derived from a combinations of a data set D.C. component and a data set A.C. component;

f. performing a mathematical regression of said mathematical model onto said normalized at least one, multi-dimensional, data set(s) and optionally said reflectance, thereby evaluating calibration parameters in said mathematical model;

said regression based calibration procedure serving to evaluate parameters in said said mathematical model for non-achromatic characteristics and/or non-idealities and/or positions of at least one selection from the group consisting of:

effective azimuthal angle of said polarizer means;

azimuthal angle of said compensator means,

retardation of said compensator means;

matrix components of said compensator means;

depolarization/Mueller Matrix components; and

azimuthal angle of said analyzer means.

g. optionally repeating steps e2. and f. utilizing a different selection in step e2. in normalizing data.

34. A method of calibrating a spectroscopic ellipsometer system as in Claim 33, in which step d. involves obtaining at least two, multi-dimensional, data set(s) of magnitude values vs. parameters selected from the group consisting of:

wavelength;

angle-of-incidence of said polychromatic beam of electromagnetic radiation with respect to a present sample;

effective or actual azimuthal angle orientation of one element selected from the group consisting of:

said polarizer means; and

said analyzer means;

over time, while at least one of said at least one compensator means is caused to continuously rotate.

35. A method of calibrating a spectroscopic ellipsometer system as in Claim 33, in which step d. involves obtaining at least two, multi-dimensional, data set(s) of magnitude values vs. parameters selected from the group consisting of:

wavelength;

angle-of-incidence of said polychromatic beam of electromagnetic radiation with

respect to a present sample;

effective or actual azimuthal angle orientation of one element selected from the group consisting of:

said polarizer means; and

said analyzer means;

over time, while at least one of said at least one compensator means is caused to continuously rotate.

36. A method of calibrating a spectroscopic ellipsometer system as in Claim 33, in which is made a selection from the group consisting of:

the compensator means is selected to provide retardance which varies by less than ninety (90) degrees (max - min) over a range of wavelengths, within a range of retardations bounded by thirty (30.0) to less than one-hundred-thirty-five (135) degrees, over a range of wavelengths defined by a selection from the group consisting of:

a. minimum wavelength is less than/equal to one-hundred-ninety (190) and maximum wavelength greater than/equal to seventeen-hundred (1700) nanometers;

b. minimum wavelength is less than/equal to two-hundred-twenty (220) and maximum wavelength MAXW greater than/equal to one-thousand (1000) nanometers;

c. within a range of wavelengths defined by a maximum wavelength (MAXW) and a minimum wavelength

(MINW) range where (MAXW)/(MINW) is at least four-and-one-half (4.5);

and

the compensator means is selected to provide retardance of between seventy-five (75) and one-hundred-thirty (130) degrees over a range of wavelengths defined by a selection from the group consisting of:

d. between one-hundred-ninety (190) and seven-hundred-fifty (750) nanometers;

e. between two-hundred-forty-five (245) and nine-hundred (900) nanometers;

f. between three-hundred-eighty (380) and seventeen-hundred (1700) nanometers;

g. within a range of wavelengths defined by a maximum wavelength (MAXW) and a minimum wavelength (MINW) wherein the ratio of (MAXW)/(MINW) is at least one-and-eight-tenths (1.8).

37. A method of calibrating a spectroscopic ellipsometer system as in Claim 36, in which the compensator is of a construction selected from the group consisting of:

comprised of a combination of at least two zero-order waveplates, said zero-order waveplates having their respective fast axes rotated to a position offset from zero or ninety degrees with respect to one another;

comprised of a combination of at least a first and a second

effective zero-order wave plate, said first effective zero-order wave plate being comprised of two multiple order waveplates which are combined with the fast axes thereof oriented at a nominal ninety degrees to one another, and said second effective zero-order wave plate being comprised of two multiple order waveplates which are combined with the fast axes thereof oriented at a nominal ninety degrees to one another; the fast axes of the multiple order waveplates in said second effective zero-order wave plate being rotated to a position at a nominal forty-five degrees to the fast axes of the multiple order waveplates in said first effective zero-order waveplate;

comprised of a combination of at least a first and a second effective zero-order wave plate, said first effective zero-order wave plate being comprised of two multiple order waveplates which are combined with the fast axes thereof oriented at a nominal ninety degrees to one another, and said second effective zero-order wave plate being comprised of two multiple order waveplates which are combined with the fast axes thereof oriented at a nominal ninety degrees to one another; the fast axes of the multiple order waveplates in said second effective zero-order wave plate being rotated to a position away from zero or ninety degrees with respect to the fast axes of the multiple order waveplates in said first effective zero-order waveplate; and

comprised of a combination of at least one zero-order waveplate and at least one effective zero-order waveplate, said effective zero-order wave plate being comprised of two multiple order waveplates which are combined with the fast axes thereof oriented at a nominal ninety degrees to one another, the fast axes of the multiple order waveplates in said effective zero-order wave plate being rotated to a

position away from zero or ninety degrees with respect to the fast axis of the zero-order waveplate;

38. A method of calibrating a spectroscopic ellipsometer system, comprising the steps of:

a. providing a spectroscopic ellipsometer for evaluating a sample comprising:

broadband electromagnetic radiation source means generating a beam having wavelengths extending over a range of at least 200 to 800 nm;

polarizer means disposed in the path of said beam;

compensator means disposed in the path of the beam, said compensator for inducing phase retardations in the polarization state of the light beam, said compensator means having characteristics other than substantially-non-achromatic, said compensator means being rotated at an angular frequency of ω ;

analyzer means that interact with the beam after the beam interacts with the sample and the compensator means;

detector means that measure the intensity of the beam after the interaction with the analyzer means at a plurality of wavelengths across the wavelength range of at least 200 to 800 nm;

said detector means generating a time varying intensity output signal simultaneously comprising 2ω and 4ω component signals, said 2ω and 4ω component signals being simultaneously present at all wavelengths measured unless the 2ω component signal is force to 0.0 by a sample presenting with an ellipsometric DELTA of 0.0 as opposed to being caused to be 0.0 by said compensator means;

b. developing a mathematical model of said spectroscopic ellipsometer system which comprises as calibration parameter(s) at least one selection from the group consisting of:

effective polarizer means azimuthal angle orientation;

present sample PSI (ψ), as a function of angle of incidence and a thickness;

present sample DELTA (Δ), as a function of angle of incidence and a thickness;

retardations of said compensator means as a function of wavelength;

compensator means azimuthal angle orientation;

matrix components of said compensator means; and

analyzer means azimuthal angle orientation;

which mathematical model is effectively a transfer function which enables calculation of electromagnetic beam magnitude detected by a detector element, given magnitude provided by said broadband electromagnetic radiation source means generating a beam having wavelengths extending over a range of at least 200 to 800 nm;

c. causing a polychromatic beam of electromagnetic radiation produced by said broadband electromagnetic radiation source means, to pass through said polarizer means, interact with a

sample caused to be in the path thereof, pass through said analyzer means, and enter detector elements in said detector means, with said polychromatic beam of electromagnetic radiation also being caused to pass through said compensator means;

d. obtaining data as described by a selection from the group consisting of:

at least one multi-dimensional data set(s); and

least two, at least one-dimensional data sets;

said data set(s) being magnitude values vs. parameter(s) selected from the group consisting of:

wavelength;

angle-of-incidence of said polychromatic beam of electromagnetic radiation with respect to a present material system;

effective or actual azimuthal angle orientation of one element selected from the group consisting of:

said polarizer; and

said analyzer;

obtained over time, while at least one of said at least one compensator is caused to continuously rotate;

said at least at least one, multi-dimensional data set(s) being obtained utilizing a selection from the group consiting of:

all of said at least one multi-dimensional data set(s), being obtained utilizing a single sample;

at least one of said at least one multi-dimensional data sets being obtained utilizing one sample, with another of said at least one multi-dimensional data sets being obtained utilizing another sample; and

at least one of said at least one multi-dimensional data set(s) being obtained with the spectroscopic ellipsometer oriented in a "straight-through" configuration wherein a polychromatic beam of electromagnetic radiation produced by said broadband electromagnetic radiation source means, generating a beam having wavelengths extending over a range of at least 200 to 800 nm, is caused to pass through said polarizer means, pass through said analyzer means and enter detector elements in said at least one detector system, with said polychromatic beam of electromagnetic radiation also being caused to pass through said compensator means but without being caused to interact with any sample other than open ambient atmosphere;

e1. optionally calculating reflectance from obtained A.C. and/or D.C. data without peforming any normalization thereupon;

e2. normalizing data in each said at least two, at least one-dimensional, data set(s) with respect to a selection from the group consisting of:

a data set D.C. component;

a data set A.C. component;

a parameter derived from a combinations

of a data set D.C. component and a
data set A.C. component;

f. performing a mathematical regression of said mathematical model onto said normalized at least one, multi-dimensional, data set(s) and optionally said reflectance, thereby evaluating calibration parameters in said mathematical model;

said regression based calibration procedure serving to evaluate parameters in said said mathematical model for non-achromatic characteristics and/or non-idealities and/or positions of at least one selection from the group consisting of:

effective azimuthal angle of said polarizer means;

azimuthal angle of said compensator means,

retardation of said compensator means;

matrix components of said
compensator means;

depolarization/Mueller Matrix
components; and

azimuthal angle of said analyzer means.

g. optionally repeating steps e2. and f. utilizing a different selection in step e2. in normalizing data.

39. A method of calibrating a spectroscopic ellipsometer system as in Claim 38, in which a selection is made from the group consisting of;

the compensator provides retardance which varies by less than ninety (90) degrees (max - min) over a range of wavelengths, said retardance being within a range of retardations bounded by (30.0) to less than (135) degrees over a range of wavelengths defined by a selection from the group consisting of:

a. minimum wavelength is less than/equal to one-hundred-ninety (190) and maximum wavelength greater than/equal to seventeen-hundred (1700) nanometers;

b. minimum wavelength is less than/equal to two-hundred-twenty (220) and maximum wavelength MAXW greater than/equal to one-thousand (1000) nanometers;

c. within a range of wavelengths defined by a maximum wavelength (MAXW) and a minimum wavelength (MINW) range where (MAXW)/(MINW) is at least four-and-one-half (4.5);

and

the compensator means is selected to provide retardance of between seventy-five (75) and one-hundred-thirty (130) degrees over a range of wavelengths defined by a selection from the group consisting of:

d. between one-hundred-ninety (190) and seven-hundred-fifty (750) nanometers;

e. between two-hundred-forty-five (245) and nine-hundred (900) nanometers;

f. between three-hundred-eighty (380) and

seventeen-hundred (1700) nanometers;

g. within a range of wavelengths defined by a maximum wavelength (MAXW) and a minimum wavelength (MINW) wherein the ratio of (MAXW)/(MINW) is at least one-and-eight-tenths (1.8).

40. A method of calibrating a spectroscopic ellipsometer system as in Claim 38, in which the compensator is selected to be of a construction selected from the group consisting of:

comprised of a combination of at least two zero-order waveplates, said zero-order waveplates having their respective fast axes rotated to a position offset from zero or ninety degrees with respect to one another;

comprised of a combination of at least a first and a second effective zero-order wave plate, said first effective zero-order wave plate being comprised of two multiple order waveplates which are combined with the fast axes thereof oriented at a nominal ninety degrees to one another, and said second effective zero-order wave plate being comprised of two multiple order waveplates which are combined with the fast axes thereof oriented at a nominal ninety degrees to one another; the fast axes of the multiple order waveplates in said second effective zero-order wave plate being rotated to a position at a nominal forty-five degrees to the fast axes of the multiple order waveplates in said first effective zero-order waveplate;

comprised of a combination of at least a first and a second effective zero-order wave plate, said first effective zero-order wave plate being comprised of two

multiple order waveplates which are combined with the fast axes thereof oriented at a nominal ninety degrees to one another, and said second effective zero-order wave plate being comprised of two multiple order waveplates which are combined with the fast axes thereof oriented at a nominal ninety degrees to one another; the fast axes of the multiple order waveplates in said second effective zero-order wave plate being rotated to a position away from zero or ninety degrees with respect to the fast axes of the multiple order waveplates in said first effective zero-order waveplate; and

comprised of a combination of at least one zero-order waveplate and at least one effective zero-order waveplate, said effective zero-order wave plate being comprised of two multiple order waveplates which are combined with the fast axes thereof oriented at a nominal ninety degrees to one another, the fast axes of the multiple order waveplates in said effective zero-order wave plate being rotated to a position away from zero or ninety degrees with respect to the fast axis of the zero-order waveplate.

41. A spectroscopic ellipsometer for evaluating a sample comprising:

broadband electromagnetic radiation source means generating a beam having wavelengths extending over a range of at least 200 to 800 nm;

polarizer means disposed in the path of said beam;

compensator means disposed in the path of the beam, said compensator for inducing phase retardations in the polarization state of the light beam, said compensator means being:

pseudo-achromatic;

in that the amount of phase retardation varies more with wavelenght, over a range of wavelengths, than is the case if a substantially-achromatic compensator is utilized; but in that the amount of phase retardation varies less with wavelength, over said range of wavelengths, than is the case if a substantially-non-achromatic compensator is utilized, said compensator means being rotated at an angular frequency of ω;

analyzer means that interact with the beam after the beam interacts with the sample and the compensator means;

detector means that measure the intensity of the beam after the interaction with the analyzer means at a plurality of wavelengths across the wavelength range of at least 200 to 800 nm;

said detector means generating a time varying intensity output signal simultaneously comprising 2ω and 4ω component signals, said 2ω and 4ω component signals being simultaneously present at all wavelengths measured unless the 2ω component signal is force to 0.0 by a sample presenting with an ellipsometric DELTA of 0.0 as opposed to being caused to be 0.0 by said compensator means;

optionally further comprising processor means for evaluating the sample based on the intensity output signal;

said compensator means being a selection from the group consisting of:

comprised of a combination of at least two zero-order waveplates, said zero-order waveplates having their respective fast axes rotated to a position offset from zero or ninety degrees with respect to one another;

comprised of a combination of at least a first and a second

effective zero-order wave plate, said first effective zero-order wave plate being comprised of two multiple order waveplates which are combined with the fast axes thereof oriented at a nominal ninety degrees to one another, and said second effective zero-order wave plate being comprised of two multiple order waveplates which are combined with the fast axes thereof oriented at a nominal ninety degrees to one another; the fast axes of the multiple order waveplates in said second effective zero-order wave plate being rotated to a position at a nominal forty-five degrees to the fast axes of the multiple order waveplates in said first effective zero-order waveplate;

comprised of a combination of at least a first and a second effective zero-order wave plate, said first effective zero-order wave plate being comprised of two multiple order waveplates which are combined with the fast axes thereof oriented at a nominal ninety degrees to one another, and said second effective zero-order wave plate being comprised of two multiple order waveplates which are combined with the fast axes thereof oriented at a nominal ninety degrees to one another; the fast axes of the multiple order waveplates in said second effective zero-order wave plate being rotated to a position away from zero or ninety degrees with respect to the fast axes of the multiple order waveplates in said first effective zero-order waveplate; and

comprised of a combination of at least one zero-order waveplate and at least one effective zero-order waveplate, said effective zero-order wave plate being comprised of two multiple order waveplates which are combined with the fast axes thereof oriented at a nominal ninety degrees to one another, the fast axes of the multiple order waveplates in said effective zero-order wave plate being rotated to a

position away from zero or ninety degrees with respect to the fast axis of the zero-order waveplate.

42. A spectroscopic ellipsometer system as in Claim 41, in which a selection is made from the group consisting of:

the compensator provides retardance which varies by less than ninety (90) degrees (max - min) over a range of wavelengths, said retardance being within a range of retardations bounded by (30.0) to less than (135) degrees over a range of wavelengths defined by a selection from the group consisting of:

a. minimum wavelength is less than/equal to one-hundred-ninety (190) and maximum wavelength greater than/equal to seventeen-hundred (1700) nanometers;

b. minimum wavelength is less than/equal to two-hundred-twenty (220) and maximum wavelength MAXW greater than/equal to one-thousand (1000) nanometers;

c. within a range of wavelengths defined by a maximum wavelength (MAXW) and a minimum wavelength (MINW) range where (MAXW)/(MINW) is at least four-and-one-half (4.5);

and

the compensator means is selected to provide retardance of between seventy-five (75) and one-hundred-thirty (130) degrees over a range of wavelengths defined by a selection from the group consisting of:

d. between one-hundred-ninety (190) and

seven-hundred-fifty (750) nanometers;

e. between two-hundred-forty-five (245) and nine-hundred (900) nanometers;

f. between three-hundred-eighty (380) and seventeen-hundred (1700) nanometers;

g. within a range of wavelengths defined by a maximum wavelength (MAXW) and a minimum wavelength (MINW) wherein the ratio of (MAXW)/(MINW) is at least one-and-eight-tenths (1.8).

43. A spectroscopic ellipsometer for evaluating a sample comprising:

a broadband light source generating a beam having wavelengths extending over a range of at least 200 to 800 nm;

a polarizer disposed in the path of the light beam;

a compensator disposed in the path of the light beam, said compensator for inducing phase retardations in the polarization state of the light beam, said compensator providing retardance which varies by less than ninety (90) degrees (max - min) over a range of wavelengths, said retardance being within a range of retardations bounded by (30.0) to less than (135) degrees over a range of wavelengths, said compensator being rotated at a an angular frequence of ω;

an analyzer that interacts with the light beam after the beam interacts with the sample and with the compensator;

a detector that measures the intensity of the light beam after

the interaction with the analyzer at a plurality of wavelengths across the wavelength range of at least 200 to 800 nm;

said detector generating a time varying intensity output signal simultaneously comprising 2ω and 4ω component signals, said 2ω and 4ω component signals being simultaneously present at all wavelengths measured unless the 2ωcomponent signal is force to 0.0 by a sample presenting with an ellipsometric DELTA of 0.0 as opposed to being caused to be 0.0 by said compensator means.

44. A spectroscopic ellipsometer for evaluating a sample comprising:

a broadband light source generating a beam having wavelengths extending over a spectroscopic range;

a polarizer disposed in the path of the light beam;

a compensator disposed in the path of the light beam, said compensator for inducing phase retardations in the polarization state of the light beam, said compensator being characterized by a fast axis azimuthal angle which varies with wavelength, said compensator being rotated at an angular frequency of ω ;

an analyzer that interacts with the light beam after the beam interacts with the sample and with the compensator;

a detector that measures the intensity of the light beam after the interaction with the analyzer at a plurality of wavelengths across the spectroscopic wavelength range;

said detector generating a time varying intensity output signal

simultaneously comprising 2ω and 4ω component signals, said 2ω and 4ω component signals being simultaneously present at all wavelengths measured unless the 2ω component signal is force to 0.0 by a sample presenting with an ellipsometric DELTA of 0.0 as opposed to being caused to be 0.0 by said compensator means.